(1) Use an incandescent light source with a color temperature range of 2800K to 3250K, or a light source with a spectral peak between 550 and 570 nanometers.

(2) Collimate the light beam to a nominal diameter of 3 centimeters and an angle of divergence within a 6 degree included angle.

(3) Use a photocell or photodiode light detector. If the light source is an incandescent lamp, use a detector that has a spectral response similar to the photopic curve of the human eye (a maximum response in the range of 550 to 570 nanometers, to less than four percent of that maximum response below 430 nanometers and above 680 nanometers).

(4) Attach a collimating tube to the detector with apertures equal to the beam diameter to restrict the viewing angle of the detector to within a 16 degree included angle.

(5) Amplify the detector signal corresponding to the amount of light.

(6) You may use an air curtain across the light source and detector window assemblies to minimize deposition of smoke particles on those surfaces, provided that it does not measurably affect the opacity of the plume.

(7) Minimize distance from the optical centerline to the exhaust outlet; in no case may it be more than 3.0 meters. The maximum allowable distance of unducted space upstream of the optical centerline is 0.5 meters. Center the full flow of the exhaust stream between the source and detector apertures (or windows and lenses) and on the axis of the light beam.

(8) You may use light extinction meters employing substantially identical measurement principles and producing substantially equivalent results, but which employ other electronic and optical techniques.

(b) All smokemeters must meet the following specifications:

(1) A full-scale deflection response time of 0.5 second or less.

(2) You may attenuate signal responses with frequencies higher than 10 Hz with a separate low-pass electronic filter with the following performance characteristics:

(i) Three decibel point: 10 Hz.

(ii) Insertion loss: 0.0 ± 0.5 dB.

(iii) Selectivity: 12 dB down at 40 Hz minimum.

(iv) Attenuation: 27 dB down at 40 Hz minimum.

(c) Perform the smoke test by continuously recording smokemeter response over the entire locomotive test cycle in percent opacity to within one percent resolution and also simultaneously record operator demand set point (e.g., notch position). Compare the recorded opacities to the smoke standards applicable to your locomotive.

(d) You may use a partial flow sampling smokemeter if you correct for the path length of your exhaust plume. If you use a partial flow sampling meter, follow the instrument manufacturer's installation, calibration, operation, and maintenance procedures.

§ 1033.530 Duty cycles and calculations.

This section describes how to apply the duty cycle to measured emission rates to calculate cycle-weighted average emission rates.

(a) *Standard duty cycles and calculations.* Tables 1 and 2 of this section show the duty cycle to use to calculate cycle-weighted average emission rates for locomotives equipped with two idle settings, eight propulsion notches, and at least one dynamic brake notch and tested using the Locomotive Test Cycle. Use the appropriate weighting factors for your locomotive application and calculate cycle-weighted average emissions as specified in 40 CFR part 1065, subpart G.

TABLE 1 TO § 1033.530—STANDARD DUTY CYCLE WEIGHTING FACTORS FOR CALCULATING EMISSION RATES FOR LOCOMOTIVES WITH MULTIPLE IDLE SETTINGS

Notch setting	Test mode	Line-haul weighting factors	Line-haul weighting factors (no dynamic brake)	Switch weighting factors
Low Idle	A	0.190	0.190	0.299

TABLE 1 TO § 1033.530—STANDARD DUTY CYCLE WEIGHTING FACTORS FOR CALCULATING EMISSION RATES FOR LOCOMOTIVES WITH MULTIPLE IDLE SETTINGS—Continued

Notch setting	Test mode	Line-haul weighting factors	Line-haul weighting factors (no dynamic brake)	Switch weighting factors
Normal Idle	B	0.190	0.315	0.299
Dynamic Brake	C	0.125	[1]	0.000
Notch 1	1	0.065	0.065	0.124
Notch 2	2	0.065	0.065	0.123
Notch 3	3	0.052	0.052	0.058
Notch 4	4	0.044	0.044	0.036
Notch 5	5	0.038	0.038	0.036
Notch 6	6	0.039	0.039	0.015
Notch 7	7	0.030	0.030	0.002
Notch 8	8	0.162	0.162	0.008

[1] Not applicable.

TABLE 2 TO § 1033.530—STANDARD DUTY CYCLE WEIGHTING FACTORS FOR CALCULATING EMISSION RATES FOR LOCOMOTIVES WITH A SINGLE IDLE SETTING

Notch setting	Test mode	Line-haul	Line-haul (no dynamic brake)	Switch
Normal Idle	A	0.380	0.505	0.598
Dynamic Brake	C	0.125	[1]	0.000
Notch 1	1	0.065	0.065	0.124
Notch 2	2	0.065	0.065	0.123
Notch 3	3	0.052	0.052	0.058
Notch 4	4	0.044	0.044	0.036
Notch 5	5	0.038	0.038	0.036
Notch 6	6	0.039	0.039	0.015
Notch 7	7	0.030	0.030	0.002
Notch 8	8	0.162	0.162	0.008

[1] Not applicable.

(b) *Idle and dynamic brake notches.* The test procedures generally require you to measure emissions at two idle settings and one dynamic brake, as follows:

(1) If your locomotive is equipped with two idle settings and one or more dynamic brake settings, measure emissions at both idle settings and the worst case dynamic brake setting, and weight the emissions as specified in the applicable table of this section. Where it is not obvious which dynamic brake setting represents worst case, do one of the following:

(i) You may measure emissions and power at each dynamic brake point and average them together.

(ii) You may measure emissions and power at the dynamic brake point with the lowest power.

(2) If your locomotive is equipped with two idle settings and is not equipped with dynamic brake, use a normal idle weighting factor of 0.315 for the line-haul cycle. If your locomotive is equipped with only one idle setting and no dynamic brake, use an idle weighting factor of 0.505 for the line-haul cycle.

(c) *Nonstandard notches or no notches.* If your locomotive is equipped with more or less than 8 propulsion notches, recommend an alternate test cycle based on the in-use locomotive configuration. Unless you have data demonstrating that your locomotive will be operated differently from conventional locomotives, recommend weighting factors that are consistent with the power weightings of the specified duty cycle. For example, the average load factor for your recommended cycle (cycle-weighted power divided by rated power) should be equivalent to those of conventional locomotives. We may also allow the use of the standard power levels shown in Table 3 to this section for nonstandard locomotive testing subject to our prior approval.

This paragraph (c) does not allow engines to be tested without consideration of the actual notches that will be used.

TABLE 3 TO § 1033.530—STANDARD NOTCH POWER LEVELS EXPRESSED AS A PERCENTAGE OF RATED POWER

	Percent
Normal Idle	0.00
Dynamic Brake	0.00
Notch 1	4.50
Notch 2	11.50
Notch 3	23.50
Notch 4	35.00
Notch 5	48.50
Notch 6	64.00
Notch 7	85.00
Notch 8	100.00

(d) *Optional Ramped Modal Cycle Testing.* Tables 1 and 2 of § 1033.520 show the weighting factors to use to calculate cycle-weighted average emission rates for the applicable locomotive ramped modal cycle. Use the weighting factors for the ramped modal cycle for your locomotive application and calculate cycle-weighted average emissions as specified in 40 CFR part 1065, subpart G.

(e) *Automated Start-Stop.* For a locomotive equipped with features that shut the engine off after prolonged periods of idle, multiply the measured idle mass emission rate over the idle portion of the applicable test cycles by a factor equal to one minus the estimated fraction reduction in idling time that will result in use from the shutdown feature. Do not apply this factor to the weighted idle power. Application of this adjustment is subject to our approval if the fraction reduction in idling time that is estimated to result from the shutdown feature is greater than 25 percent. This paragraph (e) does not apply if the locomotive is (or will be) covered by a separate certificate for idle control.

(f) *Multi-engine locomotives.* This paragraph (f) applies for locomotives using multiple engines where all engines are identical in all material respects. In cases where we allow engine dynamometer testing, you may test a single engine consistent with good engineering judgment, as long as you test it at the operating points at which the engines will operate when installed in the locomotive (excluding stopping and starting). Weigh the results to reflect the power demand/power-sharing of the in-use configuration for each notch setting.

(g) *Representative test cycles for freshly manufactured locomotives.* As specified in this paragraph (g), manufacturers may be required to use an alternate test cycle for freshly manufactured Tier 3 and later locomotives.

(1) If you determine that you are adding design features that will make the expected average in-use duty cycle for any of your freshly manufactured locomotive engine families significantly different from the otherwise applicable test cycle (including weighting factors), you must notify us and recommend an alternate test cycle that represents the expected average in-use duty cycle. You should also obtain preliminary approval before you begin collecting data to support an alternate test cycle. We will specify whether to use the default duty cycle, your recommended cycle, or a different cycle, depending on which cycle we believe best represents expected in-use operation.

(2) The provisions of this paragraph (g) apply differently for different types of locomotives, as follows:

(i) For Tier 4 and later line-haul locomotives, use the cycle required by (g)(1) of this section to show compliance with the line-haul cycle standards.

(ii) For Tier 3 and later switch locomotives, use the cycle required by (g)(1) of this section to show compliance with the switch cycle standards.

(iii) For Tier 3 line-haul locomotives, if we specify an alternate cycle, use it to show compliance with the line-haul cycle standards. If you include the locomotives in the ABT program of subpart H of this part, calculate line-haul cycle credits (positive or negative) using the alternate cycle and the line-haul cycle standards. Your locomotive is deemed to also generate an equal amount of switch cycle credits.

(3) For all locomotives certified using an alternate cycle, include a description of the cycle in the owners manual such that the locomotive can be remanufactured using the same cycle.

(4) For example, if your freshly manufactured line-haul locomotives are

equipped with load control features that modify how the locomotive will operate when it is in a consist, and such features will cause the locomotives to operate differently from the otherwise applicable line-haul cycle, we may require you to certify using an alternate cycle.

(5) See paragraph (h) of this section for cycle-changing design features that also result in energy savings.

(h) *Calculation adjustments for energy-saving design features.* The provisions of this paragraph (h) apply for locomotives equipped with new energy-saving locomotive design features. They do not apply for features that only improve the engine's brake-specific fuel consumption. They also do not apply for features that were commonly incorporated in locomotives before 2008. *See* paragraph (h)(6) of this section for provisions related to determining whether certain features are considered to have been commonly incorporated in locomotives before 2008.

(1) Manufacturers/remanufacturers choosing to adjust emissions under this paragraph (h) must do all of the following for certification:

(i) Describe the energy-saving features in your application for certification.

(ii) Describe in your installation instruction and/or maintenance instructions all steps necessary to utilize the energy-saving features.

(2) If your design feature will also affect the locomotives' duty cycle, you must comply with the requirements of paragraph (g) of this section.

(3) Calculate the energy savings as follows:

(i) Estimate the expected mean in-use fuel consumption rate (on a BTU per ton-mile basis) with and without the energy saving design feature, consistent with the specifications of paragraph (h)(4) of this section. The energy savings is the ratio of fuel consumed from a locomotive operating with the new feature to fuel consumed from a locomotive operating without the feature under identical conditions. Include an estimate of the 80 percent confidence interval for your estimate of the mean and other statistical parameters we specify.

(ii) Your estimate must be based on in-use operating data, consistent with good engineering judgment. Where we have previously certified your design feature under this paragraph (h), we may require you to update your analysis based on all new data that are available. You must obtain approval before you begin collecting operational data for this purpose.

(iii) We may allow you to consider the effects of your design feature separately for different route types, regions, or railroads. We may require that you certify these different locomotives in different engine families and may restrict their use to the specified applications.

(iv) Design your test plan so that the operation of the locomotives with and without is as similar as possible in all material aspects (other than the design feature being evaluated). Correct all data for any relevant differences, consistent with good engineering judgment.

(v) Do not include any brake-specific energy savings in your calculated values. If it is not possible to exclude such effects from your data gathering, you must correct for these effects, consistent with good engineering judgment.

(4) Calculate adjustment factors as described in this paragraph (h)(4). If the energy savings will apply broadly, calculate and apply the adjustment on a cycle-weighted basis. Otherwise, calculate and apply the adjustment separately for each notch. To apply the adjustment, multiply the emissions (either cycle-weighted or notch-specific, as applicable) by the adjustment. Use the lower bound of the 80 percent confidence interval of the estimate of the mean as your estimated energy savings rate. We may cap your energy savings rate for this paragraph (h)(4) at 80 percent of the estimate of the mean. Calculate the emission adjustment factors as:

$$AF = 1.000 - (\text{energy savings rate})$$

(5) We may require you to collect and report data from locomotives we allow you to certify under this paragraph (h) and to recalculate the adjustment factor for future model years based on such data.

(6) Features that are considered to have not been commonly incorporated in locomotives before 2008 include but are not limited to those identified in this paragraph (h)(6).

(i) Electronically controlled pneumatic (ECP) brakes, computerized throttle management control, and advanced hybrid technology were not commonly incorporated in locomotives before 2008. Manufacturers may claim full credit for energy savings that result from applying these features to freshly manufactured and/or remanufactured locomotives.

(ii) Distributed power systems that use radio controls to optimize operation of locomotives in the middle and rear of a train were commonly incorporated in some but not all locomotives in 2008. Manufacturers may claim credit for incorporating these features into locomotives as follows:

(A) Manufacturers may claim prorated credit for incorporating distributed power systems in freshly manufactured locomotives. Multiply the energy saving rate by 0.50 when calculating the adjustment factor:

$$AF = 1.000 - (\text{energy savings rate}) \times (0.50)$$

(B) Manufacturers may claim full credit for retrofitting distributed power systems in remanufactured locomotives.

[73 FR 37197, June 30, 2008, as amended at 73 FR 59190, Oct. 8, 2008; 75 FR 22985, Apr. 30, 2010]

§ 1033.535 Adjusting emission levels to account for infrequently regenerating aftertreatment devices.

This section describes how to adjust emission results from locomotives using aftertreatment technology with infrequent regeneration events that occur during testing. See paragraph (e) of this section for how to adjust ramped modal testing. See paragraph (f) of this section for how to adjust discrete-mode testing. For this section, ‘‘regeneration’’ means an intended event during which emission levels change while the system restores aftertreatment performance. For example, hydrocarbon emissions may increase temporarily while oxidizing accumulated particulate matter in a trap. Also for this section, ‘‘infrequent’’ refers to regeneration events that are expected to occur on average less than once per sample period.

(a) *Developing adjustment factors.* Develop an upward adjustment factor and a downward adjustment factor for each pollutant based on measured emission data and observed regeneration frequency. Adjustment factors should generally apply to an entire engine family, but you may develop separate adjustment factors for different configurations within an engine family. If you use adjustment factors for certification, you must identify the frequency factor, F, from paragraph (b) of this section in your application for certification and use the adjustment factors in all testing for that engine family. You may use carryover or carry-across data to establish adjustment factors for an engine family, as described in § 1033.235, consistent with good engineering judgment. All adjustment factors for regeneration are additive. Determine adjustment factors separately for different test segments as described in paragraphs (e) and (f) of this section. You may use either of the following different approaches for locomotives that use aftertreatment with infrequent regeneration events:

(1) You may disregard this section if you determine that regeneration does not significantly affect emission levels for an engine family (or configuration) or if it is not practical to identify when regeneration occurs. If you do not use adjustment factors under this section, your locomotives must meet emission standards for all testing, without regard to regeneration.

(2) You may ask us to approve an alternate methodology to account for regeneration events. We will generally limit approval to cases in which your locomotives use aftertreatment technology with extremely infrequent regeneration and you are unable to apply the provisions of this section.

(b) *Calculating average emission factors.* Calculate the average emission factor (EF_A) based on the following equation:

$$EF_A = (F)(EF_H) + (1\text{-}F)(EF_L)$$

Where:

F = the frequency of the regeneration event during normal in-use operation, expressed in terms of the fraction of equivalent tests